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Glaciers of Westland National Park

W.A. Sara

Liz Robertson
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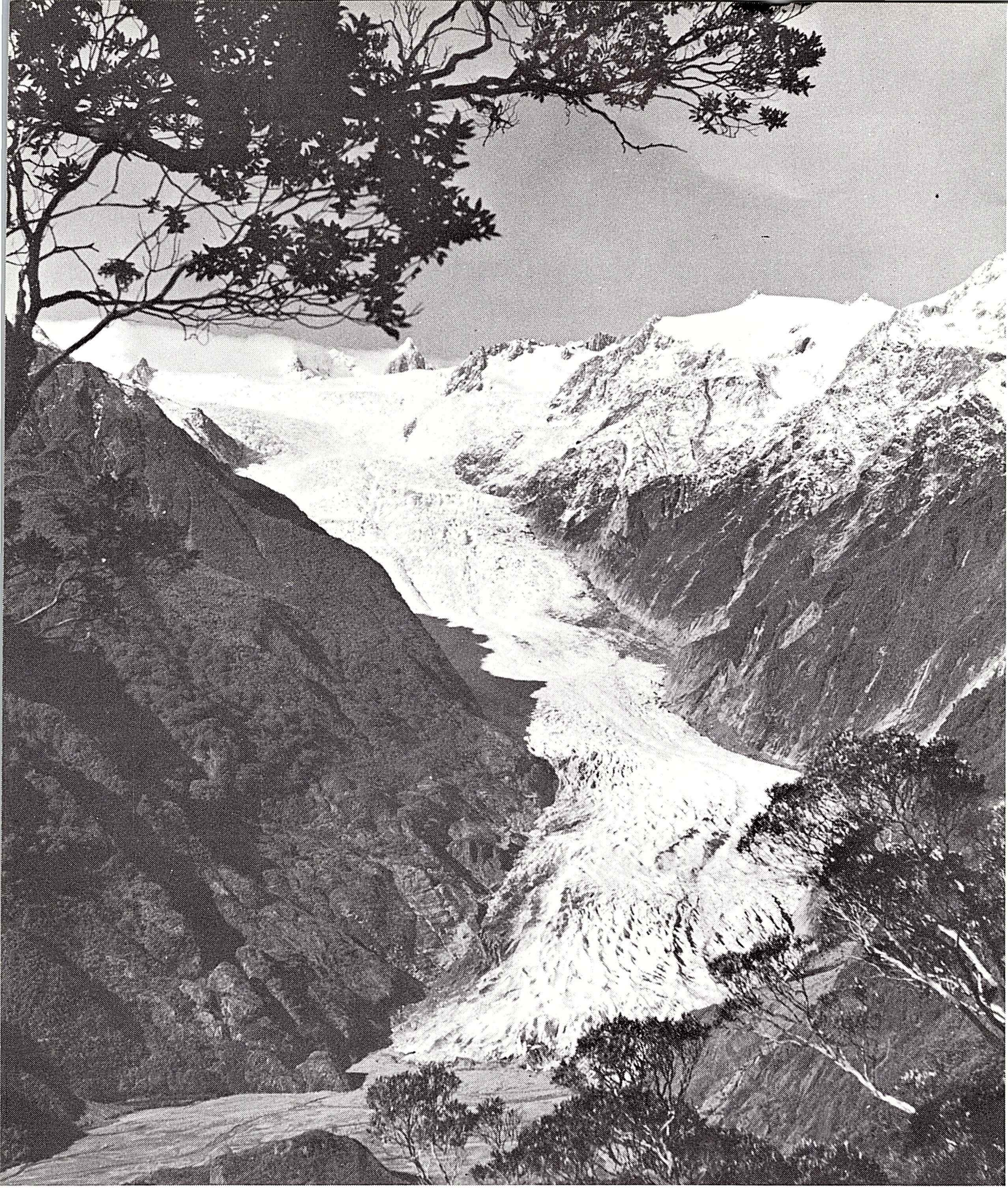

Frontispiece Franz Josef Glacier from Alex Knob, 1951.
Photo National Publicity Studios

Glaciers of Westland National Park

A New Zealand Geological Survey Handbook

W. A. Sara

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The Setting of the Glaciers

The Westland National Park was established in 1960 to embrace the major South Westland glaciers and the surrounding area. It is 88 608 ha in area, about one-quarter being glaciers and snow fields. The present map of the park, reprinted in 1964, shows the glaciers largely as they were when the explorers of the late nineteenth century saw them. They are now smaller, and their modern positions, together with accurate details of the rivers and ranges, will be shown on future maps made from aerial photographs taken in 1965.

The smaller glaciers mentioned in this handbook are not named on the geological map (fig. 5) but are shown on the maps of the park available separately or in the Westland National Park Handbook. The south-eastern margin of the park is the highest part of the main divide of the Southern Alps, many peaks being over 3000 m high. On the other side of the divide is the Mount Cook National Park embracing the major eastern glaciers.

The first published description of the glaciers was recorded in the log book of the vessel *Mary Louisa* as she sailed along the West Coast on 14 June 1859.

> "June 14th. About thirty miles to the northward of Mount Cook, and ten miles from the shore; clear, frosty morning; sun shining out upon the tops of a rugged snow-capped range of immense height . . . we saw what appeared to be a streak of mist running from between the two peaks which form the summit of the mountains. Upon a nearer approach, we concluded it must be a glacier. At noon, abreast of Mount Cook, close in shore, we could see distinctly that it was an immense field of ice, entirely filling up the valley formed by the spurs of the twin peaks, running far down into the low land. It was a pale green colour, and appeared to be quite a mile in width towards the lower end of the valley."*

The Canterbury Provincial Geologist, Haast, possibly the first European to visit the Franz Josef Glacier and certainly the first to examine it, described the scene as he observed it in 1879 from Okarito Lagoon, thus:

> "Above the forest plains rose low hillocks, also clothed with the same intensely green West Coast vegetation, over which the Southern Alps appeared a mass of snow, ice, rock, and forest. As far as

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***Lyttelton Times*, 6 July 1859.

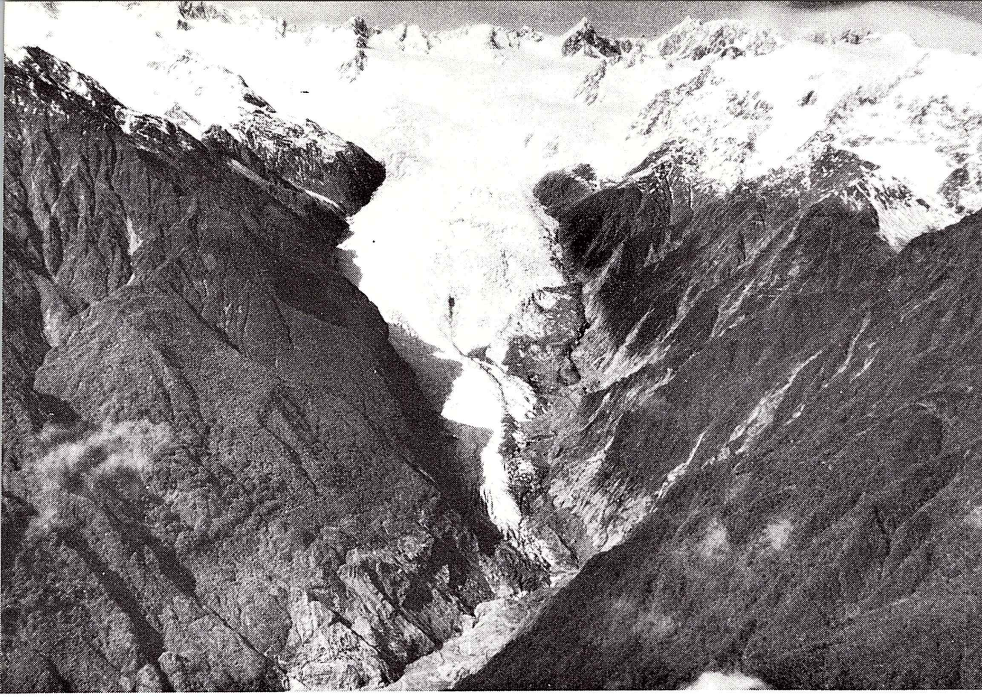

Figure 1 Aerial view of Franz Josef Glacier and snow fields, May 1964. Clearly defined trim lines, marking the changes in vegetation after various advances, can be seen.
Photo RNZAF

the eye could reach, mountain appeared behind mountain, all clad in their white garments, with which they are covered during the whole year almost entirely, becoming apparently lower until they appeared only as small points over the sea horizon—half cloud, half ghost, as a modern philosopher has said so well. But what struck me more than anything was the low position reached by an enormous glacier descending north of Mount Cook from the ranges, and appearing between the wooded hillocks at the foot of the Alps; forming with its pure unsullied ice, broken in numberless seraces, a most remarkable and striking contrast to the surrounding landscape. The sun being near his setting, new changes were every moment effected, the shades grew longer and darker, and whilst the lower portion already lay in a deep purple shade, the summits were still shining with an intense rosy hue."*

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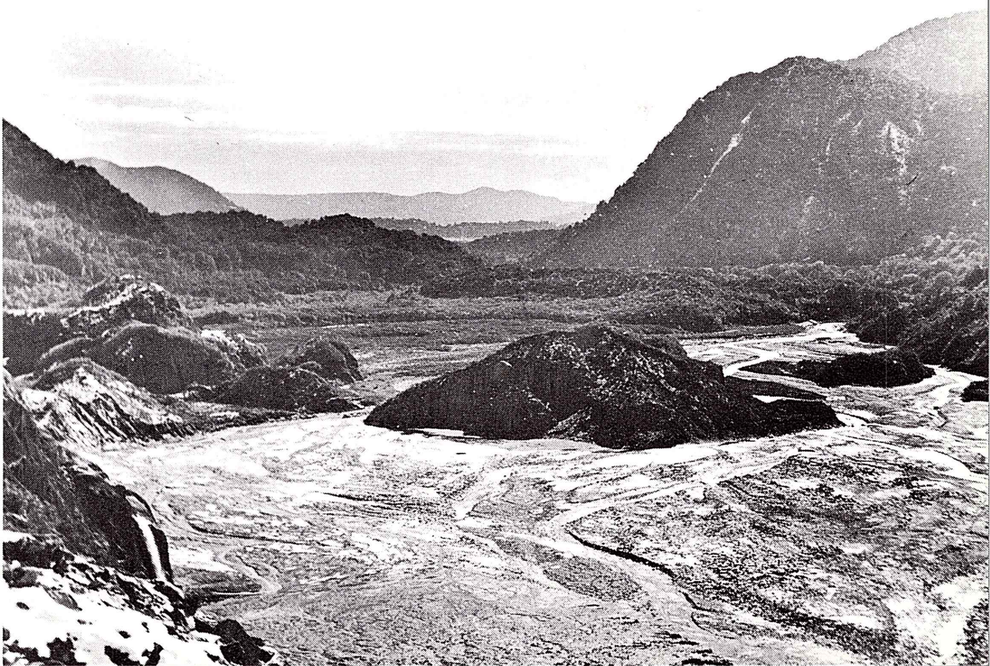
*Haast—Geology of the Provinces of Canterbury and Westland, 1879, p. 99.

Today the traveller uses the main highway from north to south through the National Park, passing through typical Westland forest dominated by rimu and kamahi and, on the mountain sides, rata, whose flower gives a glorious red colour to the forest in mid summer. Ferns are abundant, tree ferns predominating. The access roads from the main highway to both the Franz Josef (fig. 1) and Fox Glaciers are in places completely arched by trees and ferns, but some glimpses of the glaciers can be obtained. Nearer to the glaciers the change in vegetation is striking, from the older, loftier trees growing on the older moraines to the scrub vegetation on the younger moraines and outwash gravels. This vegetation, mainly coprosmas, fuchsia, wineberry, and five-finger, becomes sparser and decreases in height towards the terminal faces of the Franz Josef and Fox Glaciers, and the most recent deposits carry only lichens. These vegetation changes are well seen in the Waiho Valley (figs. 1, 2). Bare gravel flats surround Sentinel Rock and other roches moutonnées that were covered by the glacier at the end of the nineteenth century, but the older moraine ridges further down valley are clothed in thick forest.

The change in the vegetation shows most clearly on the valley sides, where well defined trim lines mark the upper limits reached by the ice

Figure 2 Looking north down Waiho Valley; the roches moutonnées are prominent landmarks. The large one in the centre of the valley is Park Rock, with Sentinel Rock at the rear of the group on the left. Down valley, the various moraine ridges can be seen, indicating stages when the glacier was much longer. *Photo R. P. Suggate*



during the various advances of the glacier in the past few centuries. Near the bottom only scanty vegetation grows on rock exposed by the most recent retreat, and upwards successive changes can be seen as small scrub gives place to older and much heavier forest (fig. 2).

The névés of the Franz Josef and Fox Glaciers are by far the largest on the western side of the Southern Alps. Snow is brought by the prevailing westerly winds, especially from the south-west in winter. On the lowlands the average annual rainfall at Franz Josef township, where little snow falls, is about 5000 mm, but within the last decade rainfalls as low as 3900 mm and as high as 7600 mm have been recorded. The average precipitation, mainly snow, on the snow fields of the Franz Josef Glacier probably exceeds 7700 mm.

Geology*

The outstanding topographic contrast between the coastal lowland and the Southern Alps, emphasised by the grandeur of the steep north-western face of the mountains, is the result of the geological processes of glacial and river erosion and deposition, and of earth movements, mainly during the last few million years. The sequence of events, simple in outline, is complex in detail: the mountains have risen faster than erosion could wear them down, even the erosion by glaciers of the Ice Age; debris of this erosion, carried down by ice and rivers, covers the hard rocks that underlie the coastal lowlands. The boundary between the rising ranges and the lowlands is clearly marked by a major geological break through the earth's surface, the Alpine Fault (figs. 3, 5), which is the greatest fault in New Zealand and a feature of great magnitude on a world scale.

East of the Alpine Fault the rocks are mainly schist (fig. 4), rocks in which the parallel arrangement of minerals results in a tendency for the rock to break into parallel-sided fragments. These rocks were originally sand and mud deposited beneath the sea, but great changes have taken place in them as a result of burial many miles beneath the earth's surface at a time when earth movements were strongly folding the rocks. The greater the depth of burial the greater were the temperatures and pressures, the greater were the consequent changes in the original rock, and the better was the resulting parallel arrangement of new minerals. These progressive changes can be followed westwards from the main divide to the Alpine Fault. At the main divide the greywacke and argillite

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*This section is abbreviated from the account by Dr R. P. Suggate, originally published in the Westland National Park Handbook (1966).

Figure 3 The front of thc Southern Alps, looking south-east from the seaward side of Franz Josef Glacier township. The Alpine Fault extends along the steep north-western front of the mountains, and morainic deposits make up the ridges in the foreground. The forest-covered ridge in the middle is the western end of a part of a terminal moraine (Waiho Loop) thought to be about 10 000 years old. Mt Elie de Beaumont (3100 m) is at top left. *Photo N.Z. Geological Survey*

are very hard but there have been few mineral changes. To the west a new mineral, chlorite, is common, and the rock begins to look more like schist. Then biotite, a dark-coloured mica, characterises the schist. Closer still to the Alpine Fault, garnet—unfortunately not of gem quality—is fairly common with the biotite.

The age of the original sediments that were changed to schists is not known for certain, but it is likely that these rocks are 200 to 300 million years old. The metamorphism of the schists and the accompanying folding are generally thought to have taken place about 150 million years ago. The folding was extremely complex in detail, particularly in the schists where tiny folds seen in some hand specimens of the rock are matched by larger folds up to 3–5 km across that are revealed by detailed geological mapping. As well as folding, faulting of the rocks took place, and the beginning of movement along the line of the Alpine Fault may date from this time. Along the Alpine Fault itself the schists are highly

Inset 2

Figure 4 Ice-smoothed valley walls of banded schist exposed by shrinkage of the Franz Josef Glacier, August 1951. Note figure holding stadia rod at bottom of rock slope.
Photo R. P. Suggate

crushed and sheared, such rocks being well exposed on the main road south-west from the Waikukupa River to the Cook Saddle. On completion of the earth movements the metamorphism ended, but the schists were probably still deep down below the surface of the earth.

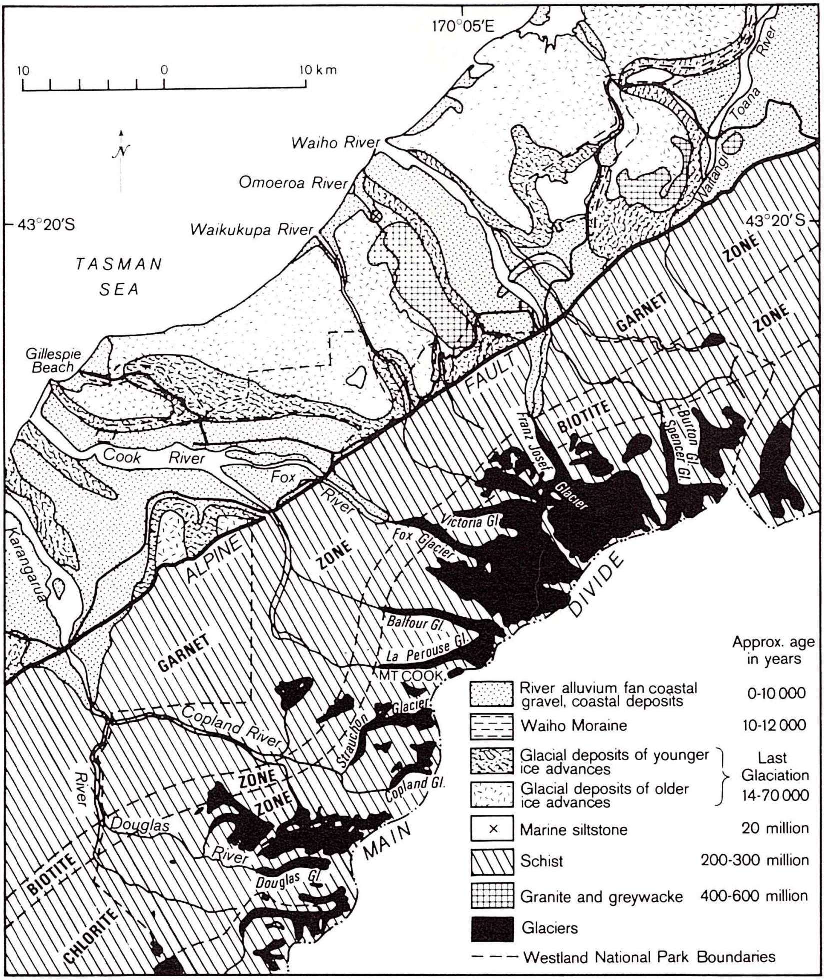


Figure 5 Geological map of Westland National Park (geology by R. P. Suggate, N.Z. Geological Survey).

Their main uplift took place during the period of earth movements of about the last 5 million years, and was greatest immediately east of the Alpine Fault, so that the most highly metamorphosed rocks are found there.

The period of the Ice Age coincided with the period of the main uplift of the Southern Alps; indeed without that uplift there would probably have been no major glaciers. There were numerous main cold periods (glaciations) during the Ice Age, separated by periods of warmth like the present day. Such were the powers of erosion of the glaciers, however, that the records of the earlier glaciations were all but destroyed during the last glaciation.

The deposits of the last glaciation consist mainly of glacier-deposited boulder gravel with a silty sand matrix, making up prominent ridges that wind through the bush-covered lowlands, east of the Alpine Fault. Gravel, sand, and silt deposited by meltwater are also widespread. The last major glacial advance took place probably 14 000 to 16 000 years ago and carried the ice from the Franz Josef valley as far as the northern end of Lake Mapourika and down the Waiho Valley as far as the coast; the moraine ridge formed by glacial debris along the margin of this glacier can be seen prominently in the forest along the western side of the Waiho Valley, 150 m or more above the valley floor. Ice from the Cook and Fox glaciers filled the Cook valley. Retreat of the ice, accompanied by stagnation of huge areas, left depressions, most of which were filled by alluvium, but where there were no main rivers the depressions were occupied by lakes. The retreat was probably accomplished by about 12 000 years ago.

Although the last glaciation was over, important fluctuations in the glacier still took place. A moraine ridge in the form of a quarter of a circle lies 4 km north of Franz Josef township and is crossed by the main road at Stony Creek; the southern part of the loop of moraine has been destroyed by the Waiho River. The ice advance recorded by this moraine, tentatively thought to have taken place about 10 000 years ago, was minor compared with those of the last glaciation, but was far more important than the fluctuations of the past few hundred or few thousand years recorded by gravels and morainic deposits in the Waiho Valley up stream from the main road bridge.

Throughout the Ice Age, movement continued at the Alpine Fault, and there is evidence that even some of the younger river gravels in the Franz Josef area have been uplifted by faulting. At Hare Mare Stream, about 180 m up stream from the road bridge, schist has been thrust over morainic gravel. It is clear that the geological processes of earth movement and of glacier fluctuation that have produced the dominant geologic and topographic features of the region are still continuing.

From Snow to Ice and Ice to Water

Glaciers are formed from nothing more than snow. The transition from snow to ice begins high up in the snow fields or névés (figs. 6, 7, 10, 21) where much of the precipitation throughout the year falls as snow, but some of this melts away in the summer. The snow line in winter is 1200 to 1500 m, but in late summer retreats to 2100 to 2400 m.

New snow contains a fairly high proportion of air trapped between the tiny, angular snow crystals. As more snow falls, its weight causes the crystals in the lower layers to pack more closely together, forcing out some of the trapped air. This process continues year by year with each snowfall.

Summer meltwater and rain soak into the snow, and under their influence the snow crystals become rounder and more closely packed. As further snow increases the pressure, the ice crystals in the lower

Figure 6 Part of Franz Josef snow field with Mt. Tasman (3223 m) in the background and Mackay Rocks in the foreground. *Photo R. Warburton*

Figure 7 Part of Franz Josef snow field with the Minarets (3048 m) in the background.
Photo R. Warburton

layers fuse into a solid mass so that all resemblance to snow disappears and clear ice is formed. When the pressure of snow and ice becomes too great it forces the lower layers of the ice to flow downhill out of the snow-field basin (figs. 8–10) to form the glacier tongue.

It has been estimated that a depth of about 20 m of snow is required to produce clear ice, and probably at least 45 m of snow and ice is required before sufficient pressure is exerted to cause the lower layers of ice to flow.

Natural wasting (ablation) of the glaciers takes place throughout the year mainly by melting. Ablation rates vary with the weather and season, probably being very slow in winter but faster in the summer, particularly during periods of warm rain. The rate also increases with decrease in altitude, and the glacier ends where the rate of ablation exceeds the rate

Figure 8 Part of main icefall, Franz Josef Glacier, with Melchior Glacier on right and Mt Spencer (2794 m) at rear. *Photo R. Warburton*

at which the ice moves downhill. Melted ice, rain that falls on the glacier, and streams from the valley sides combine to form the main river, which starts high up the glacier tongue and varies greatly in volume, mainly according to the day-to-day rainfall.

Moraines

When the ice from the névé enters the glacier tongue it may become partly covered by rock debris falling on to it from the valley walls and from any rocks that protrude through the glacier. The moving glacier erodes the rock walls and valley floor and more rock debris is incorporated in the ice. All this rock debris is known as morainic material, and when it accumulates either on the surface of the glacier, or in front and on the sides as the glacier retreats, it is called moraine. The Franz Josef Glacier (fig. 1) and the Fox Glacier (fig. 22) have heaps of moraine along the edges of the ice. Photographs taken over several years show how such heaps move down the glacier, and sometimes also, to a lesser

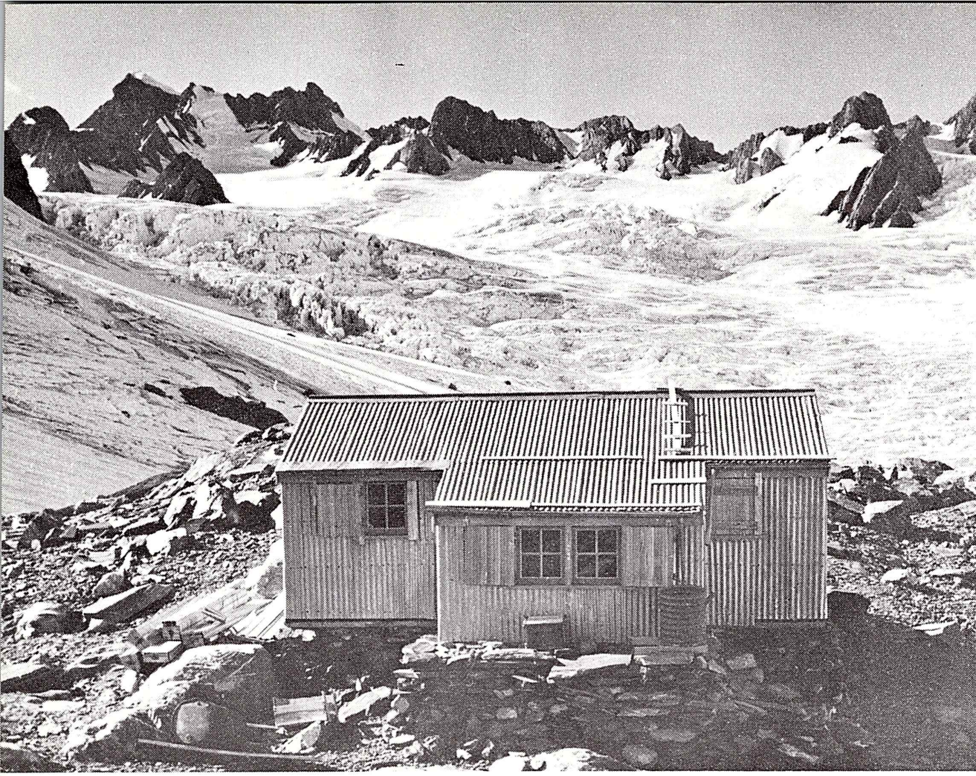


Figure 9 Part of Franz Josef Glacier, with Almer Hut in foreground and main divide in background. *Photo R. Warburton*

extent, to the sides. The lower reaches of the Balfour and La Perouse Glaciers (fig. 30) are almost entirely covered by moraine, which tends to become concentrated as ablation continually increases at lower altitudes. But this concentration, when it covers the whole surface of the glacier, tends to protect the underlying ice from ablation. Many glaciers, for example the Balfour and La Perouse in Westland National Park, and the Tasman and Murchison in Mount Cook National Park, have remained substantially the same in length, although they have shrunk greatly in thickness. In contrast, the fast-moving Franz Josef Glacier, with little moraine on its surface, has not been protected, and its changes in length have reflected short-lived changes in snow accumulation in the névé. The Fox Glacier has been somewhat protected in the lower reaches by an incomplete cover of moraine, and, although the active part of the ice has fluctuated rather as the Franz Josef has, for scores of years there have remained in the Cone Rock area substantial masses of moraine-protected dead ice, on some of which thick scrub has grown. In the end these will disappear by ablation, or they will be washed away by the river, or buried by new ice if the glacier advances.

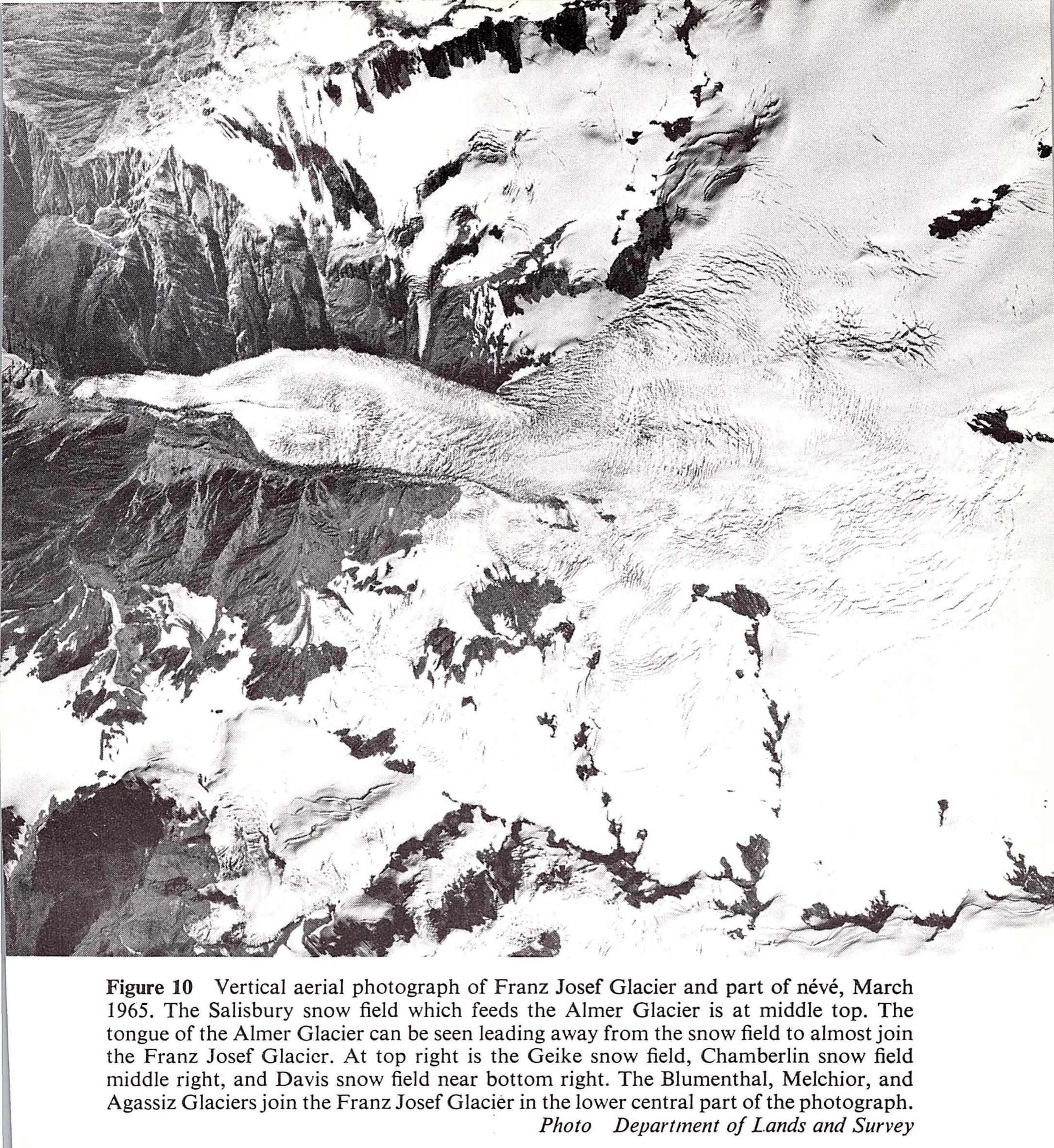


Figure 10 Vertical aerial photograph of Franz Josef Glacier and part of névé, March 1965. The Salisbury snow field which feeds the Almer Glacier is at middle top. The tongue of the Almer Glacier can be seen leading away from the snow field to almost join the Franz Josef Glacier. At top right is the Geike snow field, Chamberlin snow field middle right, and Davis snow field near bottom right. The Blumenthal, Melchior, and Agassiz Glaciers join the Franz Josef Glacier in the lower central part of the photograph.
Photo Department of Lands and Survey

Much morainic material accumulates at the front of an advancing glacier, partly by concentration, and partly by being brought up to the surface in the glacier itself, for it is found that at the ice front one layer of ice is thrust over the one below, and because these layers extend from the bottom of the glacier the thrusting drags up rock material from the valley floor. This process gives the ice a layered appearance at the terminal face (fig. 19f).

When, after an advance, a glacier front remains static and then begins to retreat, it leaves piles of accumulated morainic material in a terminal moraine. Such a terminal moraine, marking the position to which the glacier advanced, may not be preserved, since the river issuing from the retreating glacier may wash it away. Practically nothing of the small terminal moraine formed during the 1947–50 advance of the Franz Josef Glacier (fig. 17) now remains, and the gravel that built up the river bed some metres above the level existing before that advance has now almost entirely disappeared. During the advance that began in 1965 the river bed was built up, and where the river bed narrows into a gorge 2.4 km down stream from the glacier terminal, at least 30 m of gravel had accumulated, but much of this has now been eroded.

As well as morainic material deposited by the glacier and outwash gravel deposited by the river coming from the glacier, a great deal of fine "rock flour" is carried away by the river. This comes from the grinding action of rock against rock in the ice and against the valley walls and floor. It gives a blue-grey milky look to the river, characteristic of rivers coming from glaciers. The grinding smooths the walls of the valley, as clearly seen where the ice has retreated at the Franz Josef Glacier (fig. 4) and along the side of Cone Rock at the Fox Glacier.

The Changing Glaciers

Franz Josef Glacier

The névé of the Franz Josef Glacier (figs. 6, 7, 10) slopes from about 2700 m above sea level at the main divide of the Southern Alps to about 1500 m, and the glacier tongue descends at a gradient of about 260 m per km for a distance of a little more than 4.8 km to its present terminus 270 m above sea level where the Waiho River* issues from it.

*The Maori meaning of the name "Waiho" is "Smoking water"; the thin fog layer is caused by the chilling of warm moist air by contact with the ice-cold waters of the river.

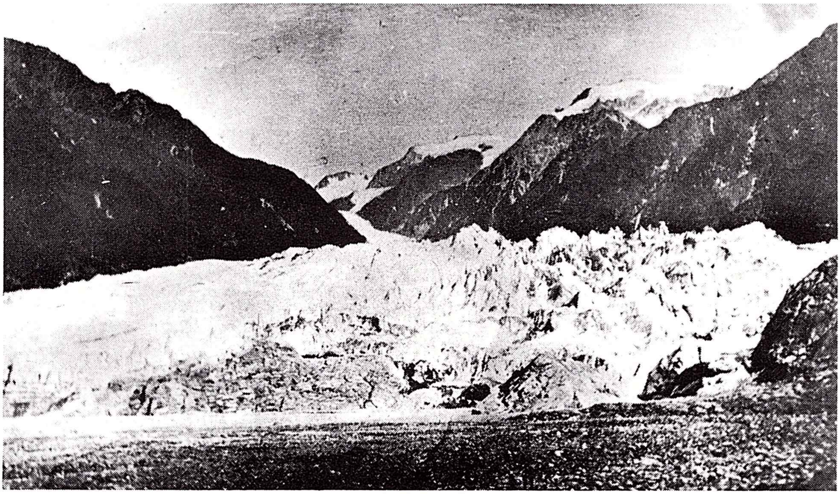


Figure 11 Franz Josef Glacier terminal face, copy of a photograph taken by H. Pringle, 1867.

Within the Southern Alps the main névé at the head of the Franz Josef Glacier, comprising the Geikie, Chamberlin, and Davis snow fields, is second in size only to that of the Fox Glacier and covers an area of 2000 ha. The total catchment area at the head of the Fox Glacier is 3200 ha.

Although visited by Haast in 1865 and named by him after the Emperor of Austria-Hungary, it was first photographed, so far as is known, by Pringle in 1867 (fig. 11). At that time the terminal face was some 2100 m down valley from its present position, near the northern side of Sentinel Rock. The face was estimated to be about 900 m wide and less than 210 m above sea level.

The first map, compiled by the explorers Douglas and Harper in 1893, indicated some recession and in 1926 Harper recorded his earlier observation that the ice had receded 90 m between 1873 and 1893. The next maps, showing the glacier and the morainic areas down valley from Sentinel Rock, were made by Greville who accompanied Bell, Director of the New Zealand Geological Survey. In his report, Bell (1910) recorded an especially remarkable advance in the preceding few years. Between March 1908 and April 1909 the ice along most of the face had advanced 30 to 50 m but over Park Rock there seemed to have been a slight retreat. Graphic illustration of the advance within the year 1907 was shown on the north-eastern side of the terminal face, where the ice had ploughed

up the valley side wrecking the steel-rod-and-wire gallery of the tourist track. Bell noted the trim lines on the valley sides and concluded that the glacier was generally retreating from a position reached during an advance "probably not more than 150 years ago". This is the advance that Lawrence and Lawrence (1965) showed to have taken place about the year 1750, judged by trees tilted at that time, and dated by counting tree rings. The advance was general in the central Southern Alps, being recorded at the Fox Glacier and also on the eastern side at the Mueller Glacier. As a result of their dating, signs have been erected on the sides of the access roads to both the Franz Josef and Fox Glaciers showing the approximate positions of the terminal face in 1750.

Our knowledge of the glacier from 1914 to 1940 is mostly provided in publications by Speight, who at intervals took photographs and assembled data from various local people, in particular Alex Graham, the noted alpine guide. In both 1914 and 1921 he recorded retreat of the glacier. Using the iron pegs placed by Bell's party during their survey of 1909 he disclosed that up to 1914 the retreat from each peg was somewhat irregular, averaging about 50 m across the terminal face. The volume of ice had also shrunk considerably. In 1921 he noted "a marked retreat of the ice since 1914, and still more since 1909". Measurements indicated that retreat of the terminal face was still irregular and Speight stated that the minimum retreat of the face since 1909 had been 100 m and the maximum 460 m. After allowing for the form of the face he found that the average retreat of the front of the glacier was about 180 m.

An advance apparently commenced in the early 1920s and in 1935 Speight suggested that since 1926 there had probably been an advance, so that in 1934 the front as a whole was further down the valley, having regained about half the amount that had been lost between 1893 and about 1920.

In 1941 Speight recorded another retreat starting about 1934 and continuing until 1946 when the terminal was at a point about opposite Rope Creek, about 920 m up valley from its 1924 position. During the 1934–46 retreat a lake formed on the western side of the valley between Park Rock and the terminal face. With successive floods in the Waiho River this lake gradually became smaller as it was filled with gravel and silt until by 1949 it was almost non-existent.

After retreat ceased in late 1946, advance began again about the middle of 1947 and continued until late 1950. This advance only regained about one-third of the distance lost during the 1934–46 retreat. Suggate (1952), reviewing the progress of the glacier from 1941, referred to changes

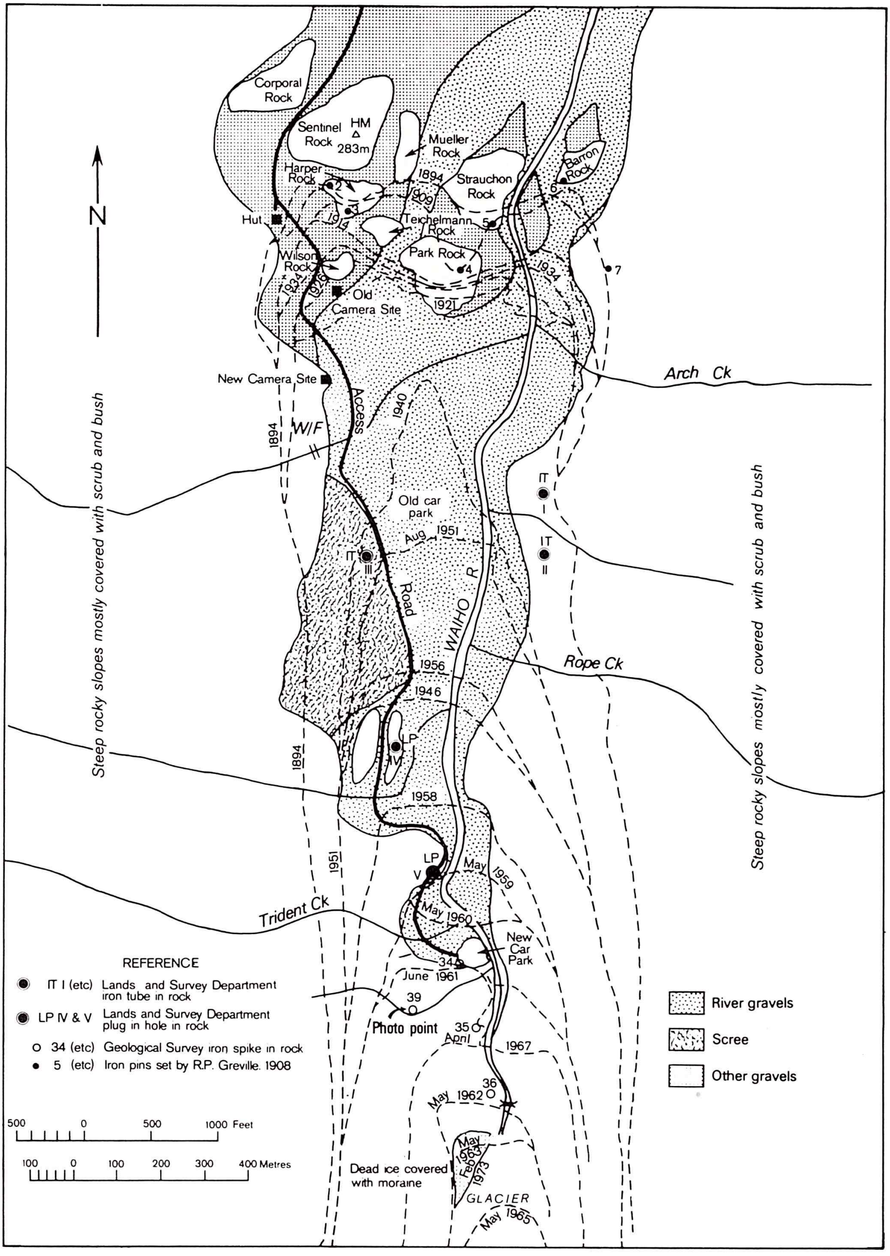


Figure 12 Retreats and advances, Franz Josef Glacier.

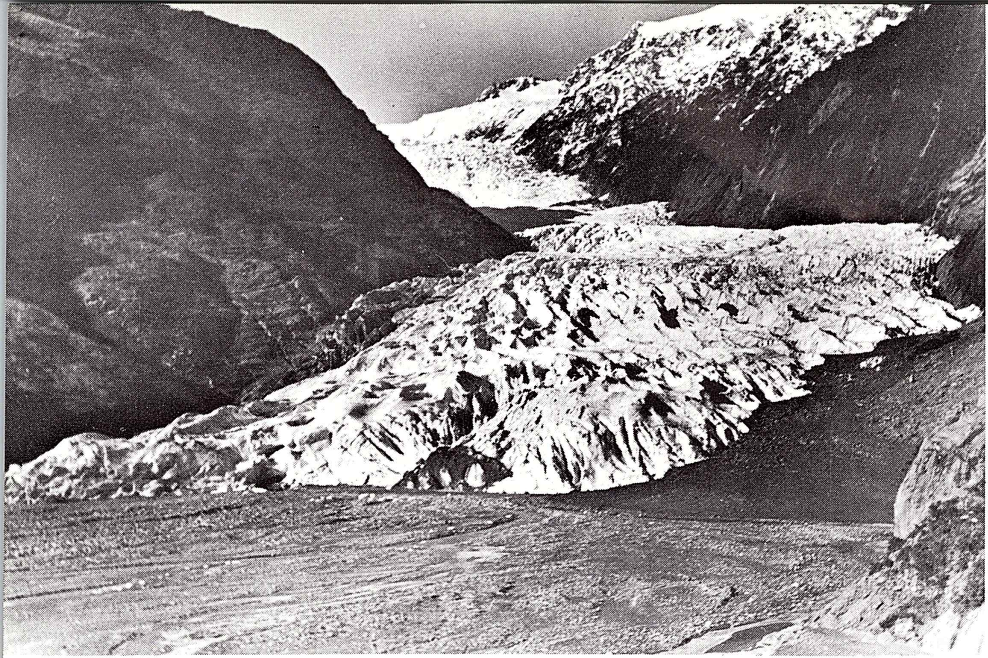


Figure 13 Franz Josef Glacier terminal face, August 1950, when the glacier was at the end of the 1946–50 advance. Photograph taken from old camera site.

Figure 14 Franz Josef Glacier, August 1951. No actual retreat is apparent at the terminal face but the ice has thinned and a terminal moraine has formed in front. Photograph from old camera site.

Figure 15 Franz Josef Glacier, January 1954. Retreat from the 1950 position is evident and the terminal moraine is now very prominent. Photograph from old camera site.

Figure 16 Franz Josef Glacier, August 1956. The terminal face occupies approximately the same position as at the end of the 1934–46 retreat. Large mounds of terminal moraine are prominent down valley from terminal face. Photograph from new camera site.

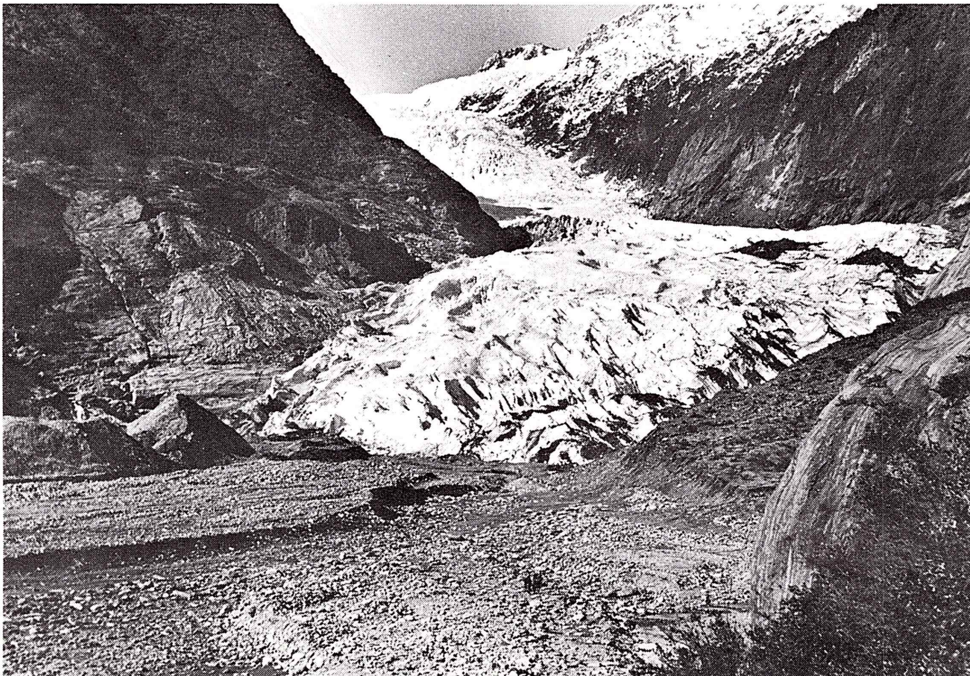
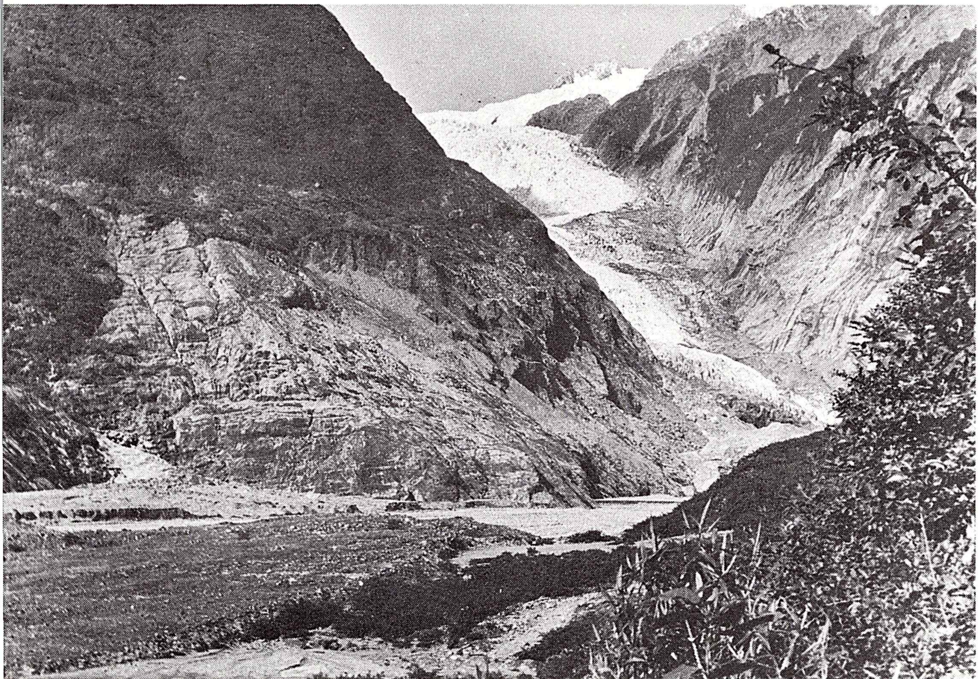


Figure 17 Franz Josef Glacier, September 1961. Very little of the terminal moraine left after the 1946–50 advance remains. Photograph from new camera site.

Figure 18 Franz Josef Glacier, April 1965, nearing the end of the 1951–65 retreat. Photograph from new camera site. *Photos N.Z. Geological Survey*



in ice level of the glacier. He stated that in 1951 the drop in level of the glacier made it appear probable that there was unlikely to be any further advance. In August 1951, with E. T. A. Annear, I carried out a stadia theodolite survey of the terminal face, the first such survey since the 1908–09 survey by Greville. This indicated that there had been no obvious advance since 1950 and that the glacier appeared to have remained fairly static even though shrinkage of ice thickness at the terminal face was evident (figs. 13, 14). The shrinkage suggested that retreat was imminent, and this proved to be so. In later years the survey was extended to follow the retreating glacier, and provides the basis for fig. 12.

The retreat lasted from late 1951 to May 1965 (figs. 15, 16). A good record is available from both weekly photographs by local people and fairly regular observations by Geological Survey staff. Some spectacular yearly retreats of up to 300 m were recorded and by 1965 the retreat from its maximum of 1950 was 1500 m and 2300 m from the 1909 peg 3 on Harper Rock (table 1). Figures 18 and 19a show the terminal face at the end of its retreat.

Some idea of the amount of ice that had wasted was obtained at the end of its retreat. In May 1965 the terminal face was only about 76 m wide and 14 m high. Measurements showed that in 1950 the glacier was some 600 m wide at this point and at least 150 m high.

An estimate of the area of the glacier tongue in 1909 has been made from Bell and Greville's map and this showed it to be 640 ha. From 1909 to the end of the 1951–65 retreat at least 600 000 000 m^3 of ice was lost. Many large ice caves were formed at the terminal face during the retreat; these alternated from side to side, depending on where the Waiho River was emerging from beneath the glacier.

In June 1965 McCormack, Chief Guide at Franz Josef, reported a slight change in the terminal face and this appears to have heralded another advance. By October 1965 a most spectacular advance of 115 m had taken place. Surveys have since been carried out at 2-monthly intervals (excluding December 1966), advances from 6 to 85 m between surveys being recorded (table 1). Figures 19a-f show the terminal face at various stages of its advance.

After an advance of 375 m up to August 1967 the glacier once again commenced to retreat. By February 1973 the terminal face had retreated 198 m at the centre and eastern side, while on the western side the retreat had reached a point of the limit of the 1950–65 retreat (fig. 20). The retreat still slowly continues.

Table 1 Movements of the Franz Josef Glacier 1951 to 1973.

Date of Survey or Observations	*Distance from Peg 3 on Harper Rock* (m)	*Amount of Movement* (m)	*Daily change since previous survey* (m/day)	*Terminal face* *Height* (m)	*Width* (m)	*Altitude at River level* (m)
		Retreat				
1951, 28 August	765				275	226
1956, 4 July	1 065	−300		12–15		
1958, 8 May	1 370	−300			210	
1959, 29 May	1 520	−150	−0.39		120	232
1960, 26 May	1 660	−140	−0.38		240	234
1961, 8 June	1 750	− 90	−0.24		180	253
1962, 1 May	2 060	−310	−0.95		150	
1963, 30 April	2 150	− 90	−0.24	27	150	
1964, 18 November	2 225	− 75	−0.13			
1965, 5 May	2 285	− 60	−0.35	15	75	274
		Advance				
1965, 18 October	2 175	+110	+0.66	90	180	—
7 December	2 090	+ 85	+1.7	90	180	—
1966, 8 February	2 030	+ 60	+0.9	90	180	—
4 April	2 010	+ 20	+0.3	30	210	—
8 June	1 980	+ 30	+0.45	30	275	—
9 August	1 950	+ 30	+0.4	76	300	—
10 October	1 930	+ 20	+0.37	45	300	—
1967, 6 February	1 910	+ 20*	+0.17	60	300	—
4 April	1 905	+ 5	+0.1	45	300	—
4 October	1 900	+ 5	+0.03	45	300	—
		Retreat				
1968, 1 May	2 005	−105	−0.50		259	—
2 December	2 045	− 40	−0.19		229	—
1969, 2 September	2 075	− 30	−0.11	18	183	—
1970, 2 February	2 075	nil	nil	6	183	—
1971, 14 September	2 090	− 15	−0.07		91	—
1973, 13 February	2 145	− 45	−0.09	6	30	273

*This is the average advance over the whole face. On the western side the advance was 36 m.

The Waiho River has its source far up under the glacier. Frequent heavy rain keeps the river in flood for much of the year. The floods cause large caverns to be formed between the base of the glacier and the valley floor, and many large falls of ice occur in these caverns, holding back very large volumes of water beneath the ice. Sometimes the water gradually washes away the fallen ice and remains flowing through its usual channel, or sometimes it finds another channel that eventually allows the river to flow out from under another section of the terminal face. Where the river emerges from under the terminal face large ice caves are usually formed and often there is much wasting of terminal ice around them.

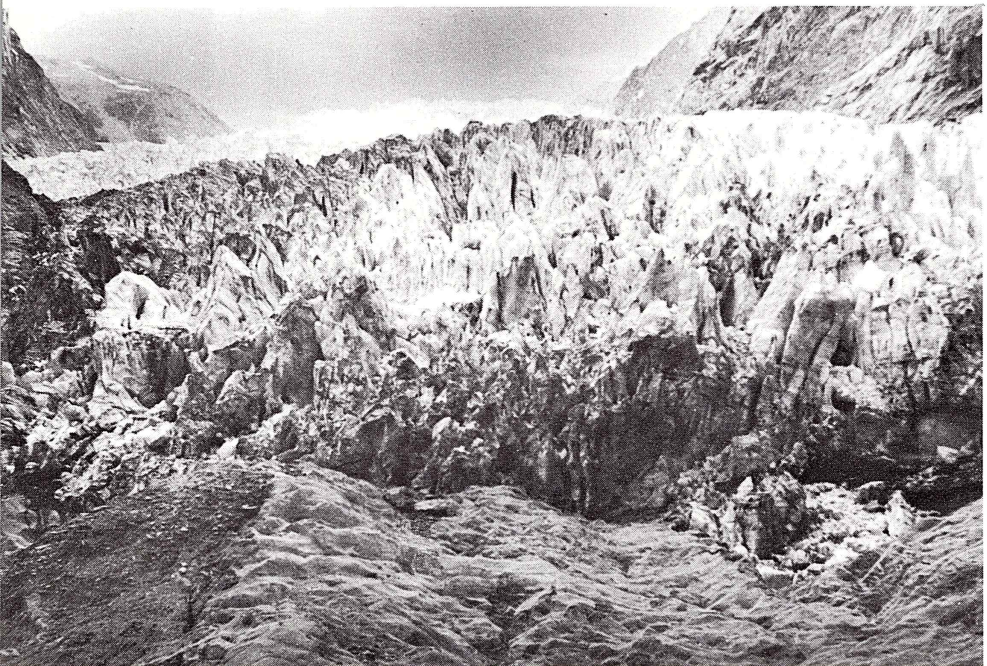
It can also happen, as in December 1965, that the pressure of water trapped under the glacier is so great that a section can no longer withstand it and a washout occurs. During a period of heavy rain on 16 and 17 December 1965, 280 mm was recorded at Franz Josef township and a large washout of ice and scree material on the western side of the glacier occurred in the early hours of 19 December. A section of the terminal face 30 m wide and the western edge of the glacier extending 300 m to Arthur's Cataract were completely washed out.

Figure 19(a–f) Photographs of the terminal face of the Franz Josef Glacier, taken from station 39. The series illustrates the rapid build up and advance of the glacier between May 1965 and June 1967. *Photos W. A. Sara*

(a) May 1965 at end of 1951–65 retreat.

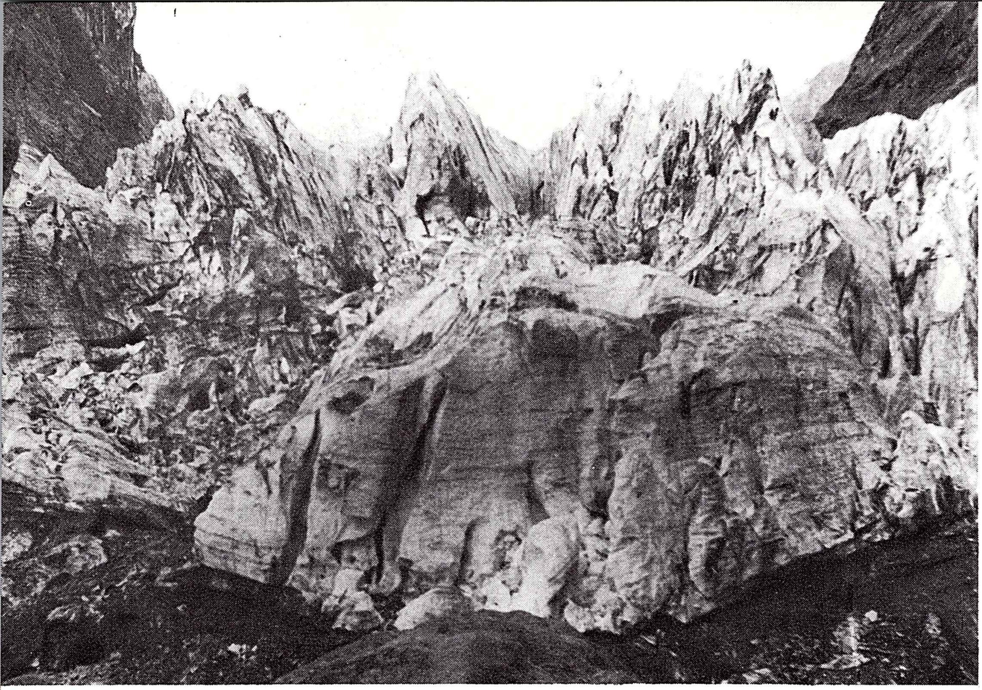
(b) October 1965.

(c) February 1966. Note how the moraine has been stripped from rock surface by the washout of December 1965.



(d) April 1966.

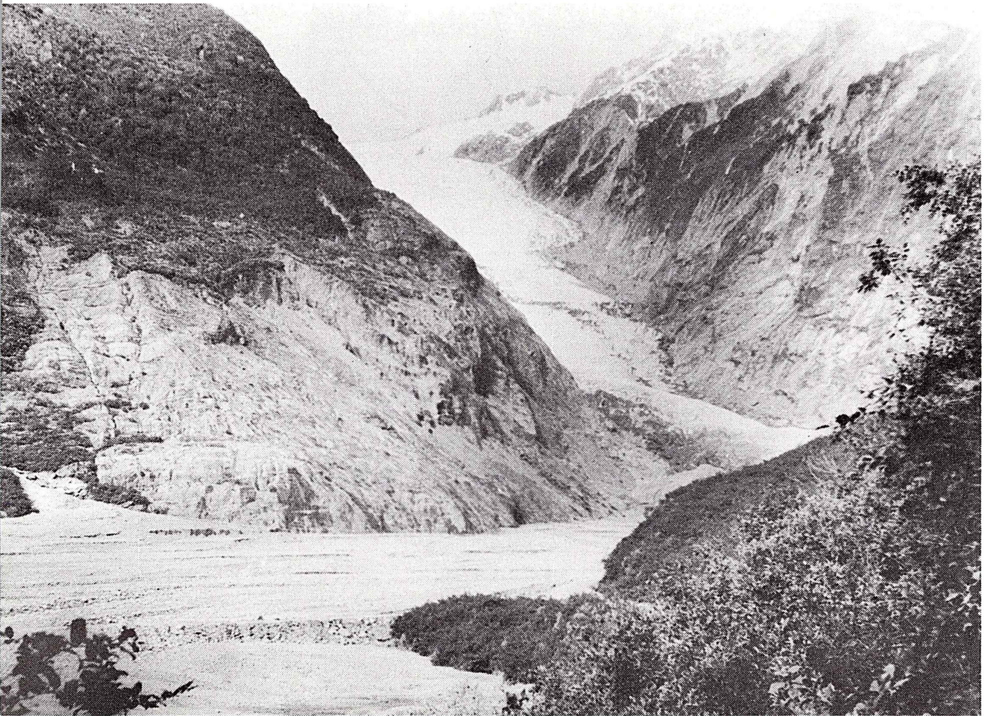
(e) August 1966.



(f) June 1967.

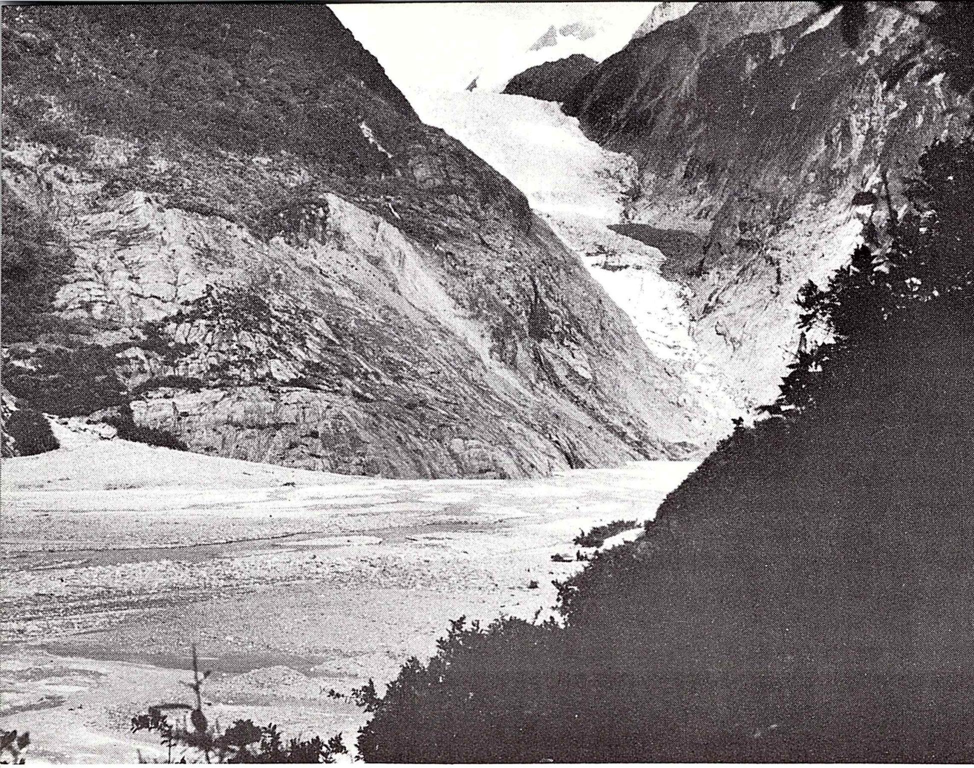
Figure 20 Franz Josef Glacier, April 1973, 6 years after commencement of 1967 retreat. Compare with *figure 18*. Photograph from new camera site.

Photo N.Z. Geological Survey



December 1976 Franz Josef Glacier. The terminal face, from the new photo point (station 39). Figures in the left foreground help to show the scale.

March 1978 Franz Josef Glacier. *Photos Westland National Park Board*



Above The Franz Josef Glacier, from the New Camera Site, April 1978.

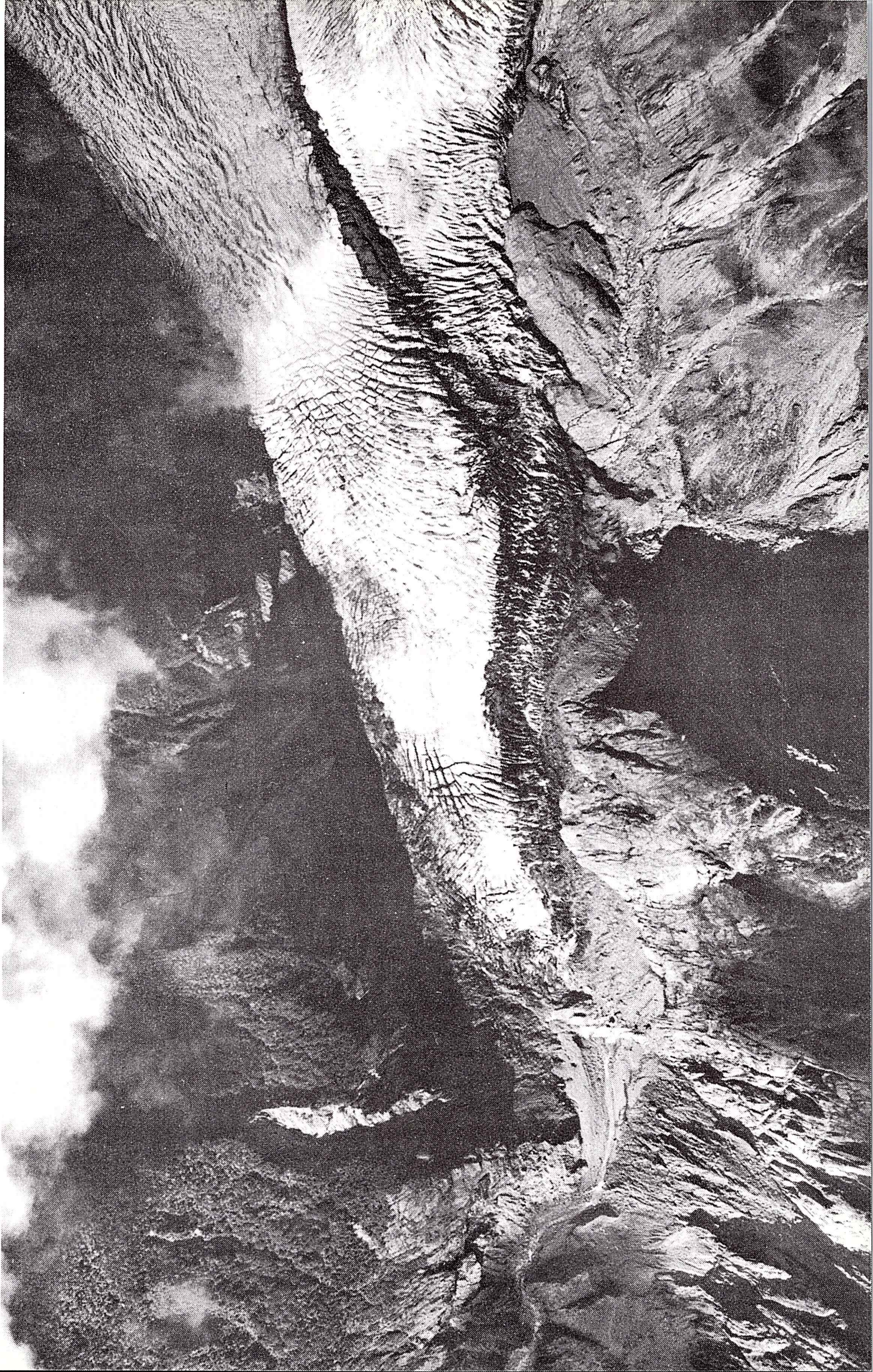
Photo Westland National Park Board

Opposite A vertical photograph of Franz Josef Glacier taken in May 1978 clearly shows the crevasses and pressure ridges. The New Car Park is at the bottom edge of this view.

Photo N.Z. Geological Survey

Next Page The Fox Glacier, from Cone Rock, September 1978. (May be compared with the front cover photograph of the glacier in 1966.)

Photo Westland National Park Board



So great was the volume of water, ice, and scree material that ice was carried to the Tasman Sea 19 km away. Ice was caught up in trees along the river sides and also piled up on the access road, a bulldozer being required to clear it. Where the river emerges from the gorge to meet the more or less flat valley floor, scree material raised the river bed by up to 18 m and successive floods have raised it by a total of about 30 m. It is calculated that at least 750 000 m^3 of ice and probably as much scree material were carried away by the December flood.

In late January 1967, after two periods of rain when 920 mm were recorded at the township, a large cave-in of ice occurred at the foot of the main icefall. Observers in an aeroplane claim that the gravel bed of the river was visible at the bottom of the hole. Unfortunately, no indication of the depth of the hole could be obtained. With the normal down-valley movement and ice falling from above, the hole gradually filled in, but again in late March 1967 after another period of heavy rain the cave reappeared, and was estimated to be about 0.4 km in diameter.

Fox Glacier

The Fox Glacier was originally named the Albert by Haast, and a large parallel glacier to the north, almost joining the Albert, was named the Victoria. The name Albert persisted for a number of years but was changed to Fox as a compliment to Sir William Fox who visited the area during his term as Prime Minister of the Colony. The main upper section within the névé still retains the original name of Albert.

Situated only about 27 km by road south of Franz Josef, the Fox Glacier has behaved similarly to its counterpart, although retreats and advances have not all coincided. In comparison with the Franz Josef, very little has been recorded about the movements of the Fox Glacier.

As with the Franz Josef Glacier, the Fox névé (fig. 21) is at about 2700 m on the main divide. The glacier tongue is a little over 6.4 km long and descends at a gradient of about 190 m per km to the terminal face about 240 m above sea level.

The glacier was visited by Haast in 1865 and by Cox in 1876, but it was not until 1894–95 that Douglas, assisted by Wilson, carried out the first detailed survey of the area. At that time the terminal face was down valley from Cone Rock. Douglas's comments (1896) on the lower part of

Figure 21 Part of Fox Glacier snow fields. *Photo R. Warburton*

the glacier are particularly pertinent: "This glacier is also singular in that it appears to be dying out in the middle, not retreating from its terminus, as it is generally supposed glaciers do. From the terminus, for about 50 chains [990 m] up the valley, the ice is almost completely covered with morainic drift. This ice slopes up to a height of 300 ft. [90 m] or 400 ft. [120 m], then it becomes clear, and slopes away down towards the ice-fall, fed by the *névés* of the main range."

The dying of the lower part of the glacier has continued throughout the 75 years since Douglas saw it. Irregular down-wasting below the morainic cover led to the isolation of patches of dead ice, while the limit of the centre part of the glacier retreated up valley, although Speight (1940) suggested a possible minor advance in 1934. Suggate (1950) thought that the glacier had remained in a fairly static position from at least 1934 up to 1950. From 1951, however, retreat was evident and continuous up to early 1964 when a small advance took place. At the end of the retreat in 1964 the terminal face was about 2 km from its 1894–95 position.

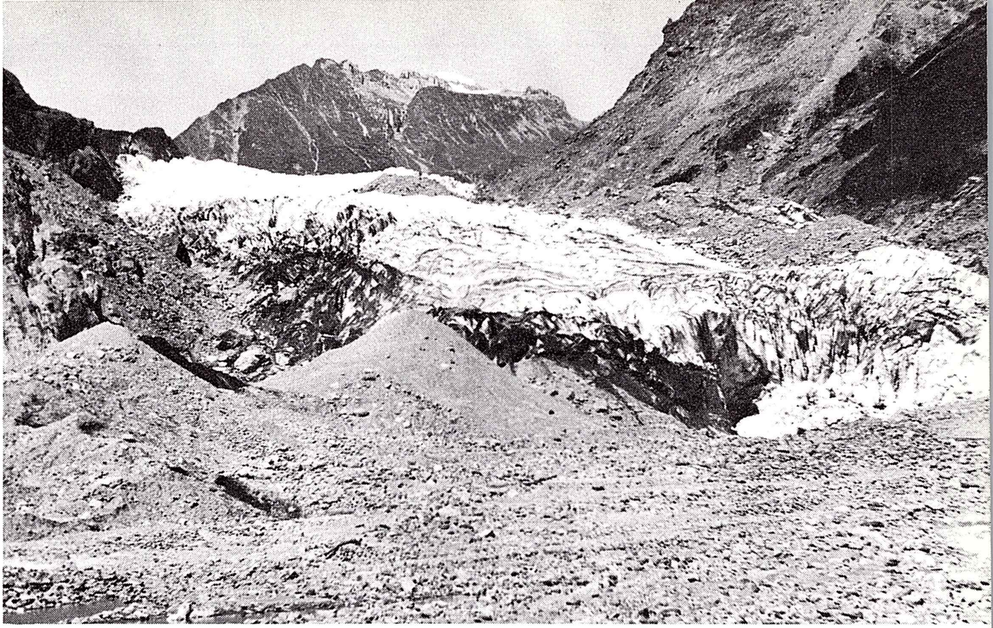


Figure 22 Fox Glacier, February 1967. Immediately in front of the terminal face are moraine-covered mounds of dead ice. The mound in the centre of the photograph was moved by the advance of the terminal face. Chancellor Ridge is in middle background.

Photos W. A. Sara

Figure 23 One of the many mounds or blocks of dead ice in the Fox River valley left after the 1951–65 retreat. Cone Rock, a prominent roche moutonnée 277 m above the valley floor, is in background. Professor Lawrence, University of Minnesota, USA, has established that the eighteenth century ice maximum rose to the top of this rock.

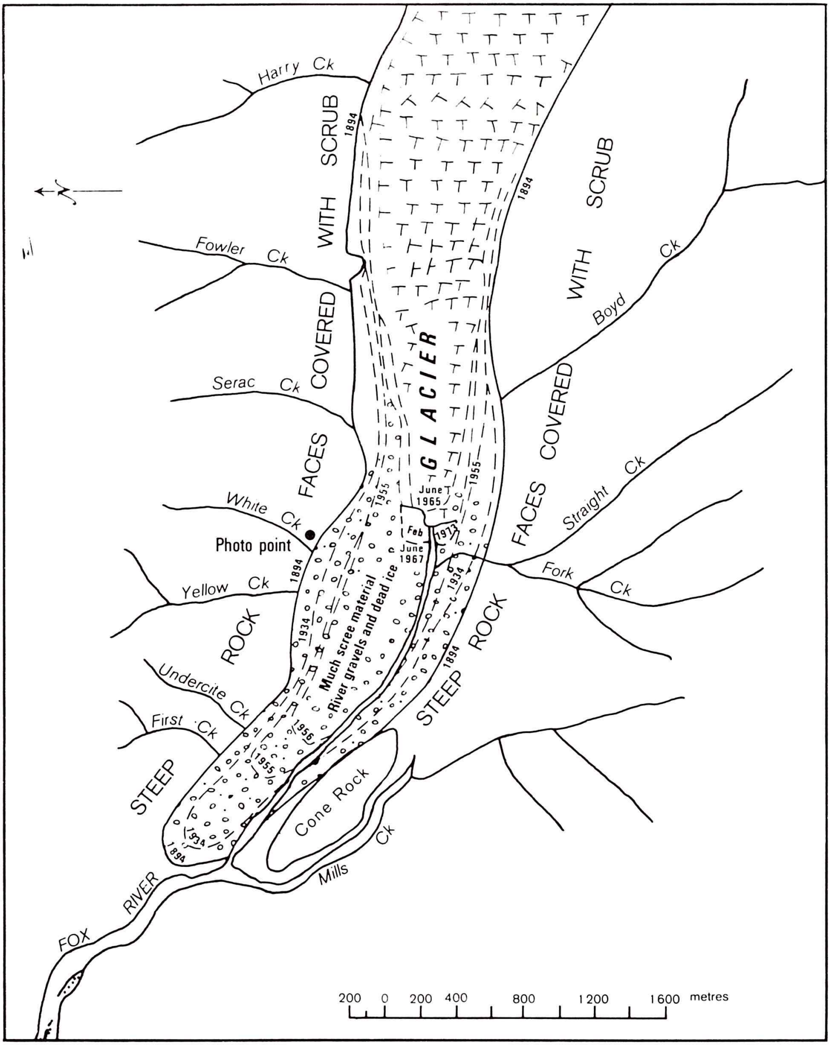


Figure 24 Map showing terminal positions, Fox Glacier. Observations by Douglas and Wilson 1894 (*in* Douglas 1894); Speight 1934 (*in* Speight 1935); Gunn 1955, 1956 (*in* Gunn 1964); Sara 1965, 1967 (*in* Sara 1968), 1973 (unpub. obs.).

Figure 25 RIGHT, ABOVE Fox Glacier terminal face, June 1965. The marker post was set in position by Mr J. H. Taylor, National Park ranger, Fox Glacier.

Figure 26 RIGHT, BELOW Fox Glacier terminal face, July 1966. The advance (about 52 m from June 1965) was such that the marker post could not be located in the centre of the camera viewfinder and still obtain a view of the edge of the terminal face so that it was necessary to swing the camera. Ridges of moraine being thrust up by the advance can be seen in the foreground. *Photos J. H. Taylor*

Figure 27 Fox Glacier terminal face showing river flowing from ice cave, February 1967. Note broken nature of face due to pressure. *Photo W. A. Sara*

The terminal face remained static until June 1965, when a slow but steady advance began. Many large blocks of dead ice (fig. 23) left during the retreat were still prominent in front of the active ice, and in 1967 the power of the advance was enough to push these blocks immediately ahead of it. From photographs taken by Mr J. H. Taylor (ranger, Westland National Park) (e.g., figs. 25, 26) it was possible to observe progress, but no accurate distances were obtained. Limited stadia theodolite surveys of the terminal face show the advance from June 1965 to February 1968 to be almost 183 m. Since then retreat has been spasmodic and by February 1973 the retreat in the centre of the glacier amounted to 91 m, and on the northern side the terminal was back to the 1965 position. Most of the known positions of the active terminal face at various times are shown on fig. 24.

Other Glaciers

Within the boundaries of the Westland National Park 57 glaciers have been named in addition to the Franz Josef and Fox Glaciers. Although all are smaller than the two main glaciers, about 29 can be classed as large or secondary, the remainder being quite small. With one or two exceptions all the névés are more than 2100 m above sea level and all the terminal faces are at least 900 m above sea level (fig. 28), that is, much higher than the Franz Josef at about 275 m and the Fox at about 240 m.

Except for the major glaciers, the only published maps for many years recorded the glaciers as they were first seen mainly towards the end of last century. Only since the aerial photography of 1965 has it been possible to obtain accurate knowledge of them and to draw accurate maps not only of the glaciers themselves (Wardle 1973; figs. 12–25) but also of the mountains within which they lie.

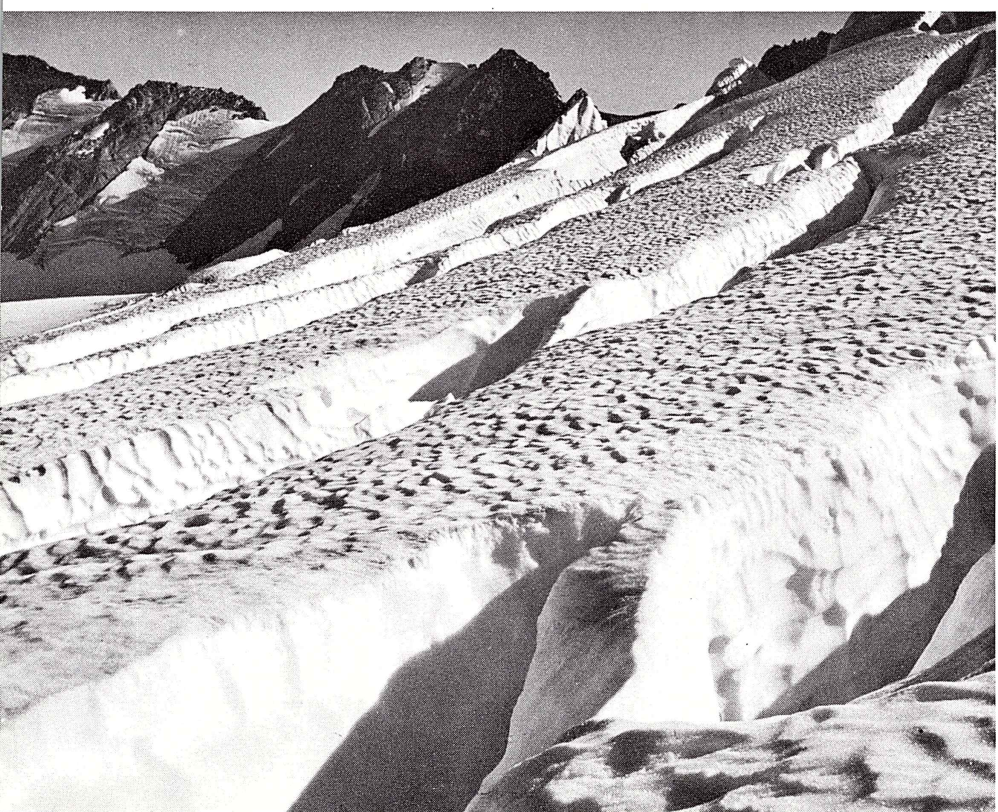
Figure 28 Top of Franz Josef Glacier, icefall with Melchior Glacier at top left-hand corner and Salisbury snow field middle right. *Photo R. Warburton*

The Franz Josef is fed by a number of high-altitude minor glaciers. The Blumenthal, Melchior, and Agassiz Glaciers (fig. 10) on the western side are at a higher level than the Almer (fig. 29) on the eastern side. During the 1951–65 recession of the Franz Josef Glacier the Almer also receded and became detached from the Franz Josef, and has not joined it again (fig. 10).

The Fox Glacier névé also is fed by a number of smaller glaciers. On the south-western side are the Jewel and Abel Jansen Glaciers and on the north-eastern side, the Explorer Glacier. These are fairly minor glaciers compared with the Albert, which is a continuation of the upper reaches of the Fox Glacier and is probably mainly névé. The Explorer is also probably mainly névé.

All the glaciers west of the main divide are in retreat (Wardle 1973). Of the largest of the minor glaciers, the Burton and Spencer east of the Franz Josef, the Victoria north-east of the Fox, and the Balfour, La Perouse, Strauchon, Douglas, Horace Walker, and Copland south-west of the Fox all show evidence of retreat. All except the Horace Walker are moraine-covered, particularly in the lower parts, and a few have almost

Figure 29 Large crevasses, head of Almer Basin; Stirling Rocks in background. *Photo R. Warburton*



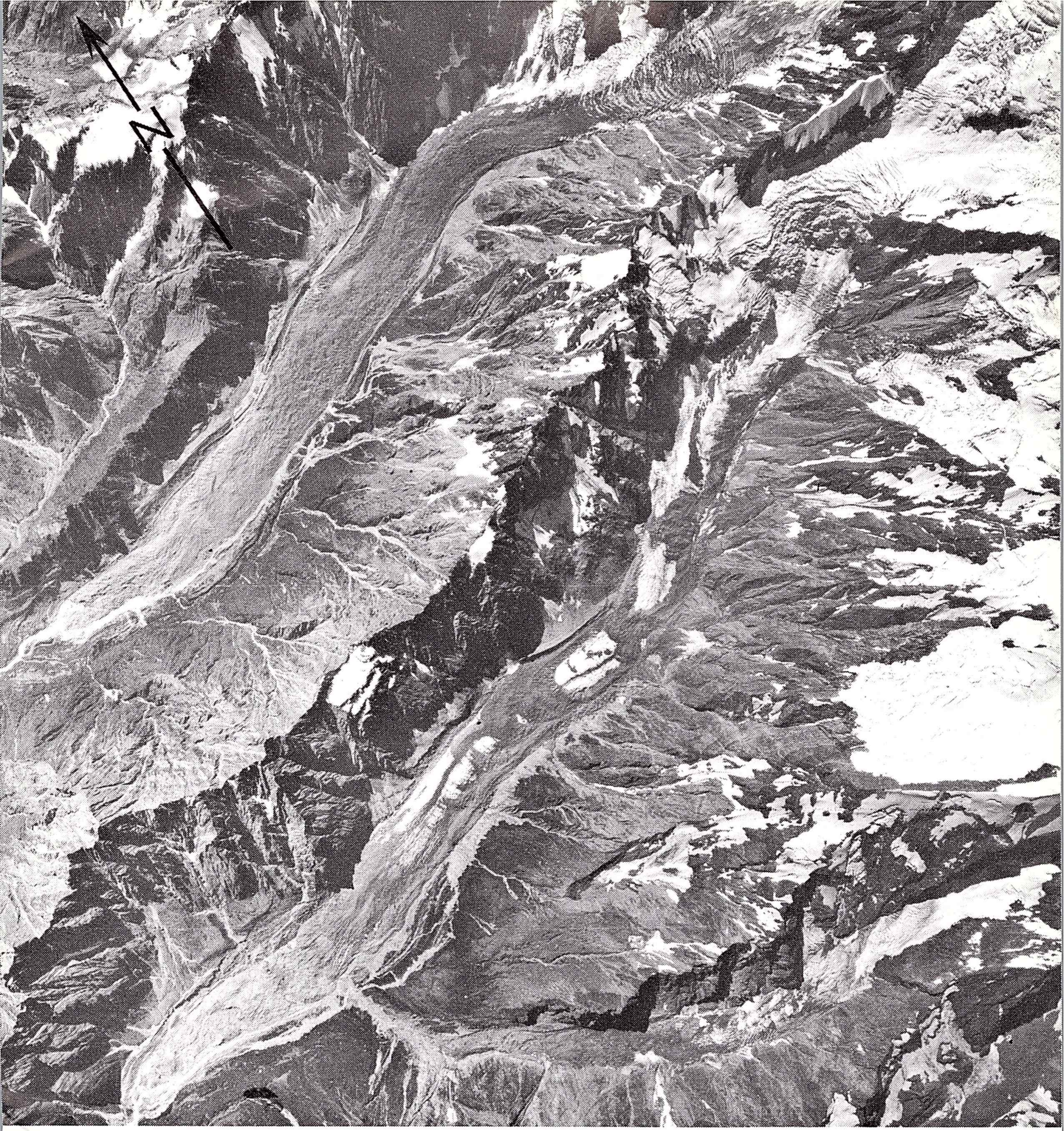


Figure 30 Vertical aerial photograph (March 1965) of névé areas and tongues of the Balfour (upper) and La Perouse (lower) Glaciers separated by the Balfour range. The two glaciers differ somewhat; the Balfour's main source of snow appears to be avalanche snow, whereas the La Perouse flows directly from its névé. Both glaciers are fairly well covered with moraine and any loss of ice at their terminals is due to wasting away rather than to retreat. On the lower right is Gulch Glacier. The Main Divide runs parallel to the right hand edge. *Photo Department of Lands and Survey*

the whole of their glacier tongues covered, which suggests that loss of ice in general is due to wasting away even more than to retreat.

Aerial photographs taken in 1965 (fig. 30) show that the Balfour and La Perouse Glaciers are, owing to inaccurate early surveys, longer and narrower than as shown on published maps. Of the large number of minor glaciers shown on published maps, many, particularly the north-facing ones, notably the Spa, Fritz, and most of those on the north side of the Sierra Range facing the Copland River, have disappeared or been reduced to mere snow fields. Some of these minor glaciers had in the past contributed ice to larger glaciers such as the Burton and Spencer, but since their recession they no longer do so.

A comparison of aerial photographs with published maps shows that there has been considerable shrinkage away from the sides of the valleys, and several glaciers have lakes in front of them, showing that there has been some retreat. In 1905 between one-third and one-fifth of the lengths of the tongues of some of these glaciers were inactive, and the Victoria and Spencer showed the lowest sections of about one-tenth of their lengths to be completely stagnant. It seems probable that there have been discontinuous fluctuations in ice supply. In 1971 the snout of the Spencer Glacier was wasting, but the trunk had increased in thickness (Wardle 1973).

The Strauchon, Marchant, Copland, and Douglas Glaciers appear to be all dead ice. They are cut off at their tops from the snow fields, and their main sources of snow are avalanches mainly from the north sides.

The Horace Walker Glacier has built a massive, broad-topped moraine along its southern margin. Fairly well defined crests on the inner and outer margins carry grasses, ferns and shrubs (Wardle 1973). Except for a small covering of moraine on the north-east side of the tongue, the ice was clear from the terminal face to the névé in 1965. Several well defined bulges or waves of ice on the tongue suggest that the glacier was active then. In contrast with many of the other glaciers the tongue had not separated from the cirque ice, although it seems to have been at least 1 km shorter than shown on maps. Wardle (1973) reported the glacier to be receding.

Causes of Glacier Fluctuations

For glaciers to remain unchanged in size the climate would have to remain unchanged. The year-to-year differences in precipitation, temperature, and sunshine would have little effect on a long gently sloping glacier,

if on the average these factors remained unchanged. But short, steep glaciers like the Franz Josef and Fox react quickly to changes and show many fluctuations related to those of ice accumulation over a few years.

These short-term fluctuations of the Franz Josef and Fox Glaciers are superimposed on the long-term decline that is shown by almost all glaciers in New Zealand and throughout the world. Such a decline can be caused only by a world-wide climatic change, one that in the last century has been less favourable to preservation of glaciers. Such a climatic fluctuation could last several centuries or several thousand years. About 1750, the Franz Josef and Fox Glaciers were both about 3.3 km longer than they are now, after a period during which they had probably been much smaller, according to the studies of Professor and Mrs D. B. Lawrence (1965). The historic record began in the late nineteenth century, with the first sightings of the glaciers by Europeans. Meteorological observations began about the same time at settlements further north along the West Coast.

In 1950 Suggate reviewed knowledge of the Franz Josef Glacier's fluctuations in relation to meteorological records. By plotting the accumulated difference in annual rainfall at Hokitika against the movement of the terminal face of the Franz Josef Glacier from 1894 to 1949 he inferred that there was ". . . a lag of about 5 years between periods of high or low precipitation and a corresponding advance or retreat of the glacier". The Hokitika figures were used because they provided the longest reliable record. Rainfall has been recorded at the Franz Josef township since 1954, and in general the seasonal trends at both Franz Josef and Hokitika, 100 km to the north-east, are similar. Rainfall trends at Hokitika over the last 15 years indicate that this estimated time lag no longer holds, as it does not account for the recent behaviour of the glacier.

Later Suggate (quoted by Sara (1968)) suggested an alternative correlation with winter precipitation, noting a particularly high value for the winter of 1962. By then the glacier was so much shorter than it had been when the 5-year lag was suggested in 1950 that an advance in 1965, indicative of a 3-year lag, was reasonable. Soons (1971) suggested that other factors could offset the effects of high winter precipitation.

Since retreat began in 1967 the glacier has lost almost half of its 1965–67 gain in length. The total rainfall for 1968 was higher than for 1962, although the winter precipitation was slightly less. Reports indicate that despite lower winter precipitation there were large snowfalls in late autumn and early spring. These, however, did not affect the retreat of the glacier which was still continuing in early 1973.

Rates of Movement

A glacier travels in much the same way as a river, with a much faster rate at the middle than at the sides.

The speed of the glacier depends on a number of factors, one of which is the general slope of the valley floor. Glaciers on the western side of the main divide have greater rates of flow than those on the eastern side because the general slope of the valleys is much steeper. Another important factor is the volume of ice that has to be transported, so that when a glacier is advancing it is to be expected that its flow would usually be greater than when retreating. The flow rate will also tend to increase after a period of high precipitation and decrease after a period of low precipitation. In the glacier tongue the speed generally diminishes from the névé to the terminal face, although if the valley floor beneath the glacier is very irregular the speed increases where the glacier thins over a hump. Movement in the névé is much slower because the ice is not confined in a narrow valley.

A number of attempts have been made to measure the rates of movement at both the Franz Josef and Fox Glaciers, the first by Harper (1894) at the Franz Josef and by Wilson (1896) at the Fox. Recent work, particularly by Gunn in 1955, shows that throughout the glacier tongue the rates are lower than at corresponding positions 50 to 60 years before. This is to be expected because the glacier has greatly diminished. Especially near the terminal face the rate of movement of an advancing glacier will tend to be greater than that of a retreating glacier, and measurements by McSaveney and Gage in 1966, while the glacier was advancing, show notably higher rates than Gunn's. Maximum rates obtained at the Franz Josef Glacier by different observers are compared in fig. 31, all measurements being near the centre of the glacier. There are very few data available on which to draw profiles of the glacier and of the valley beneath, but the general comparison is probably broadly correct.

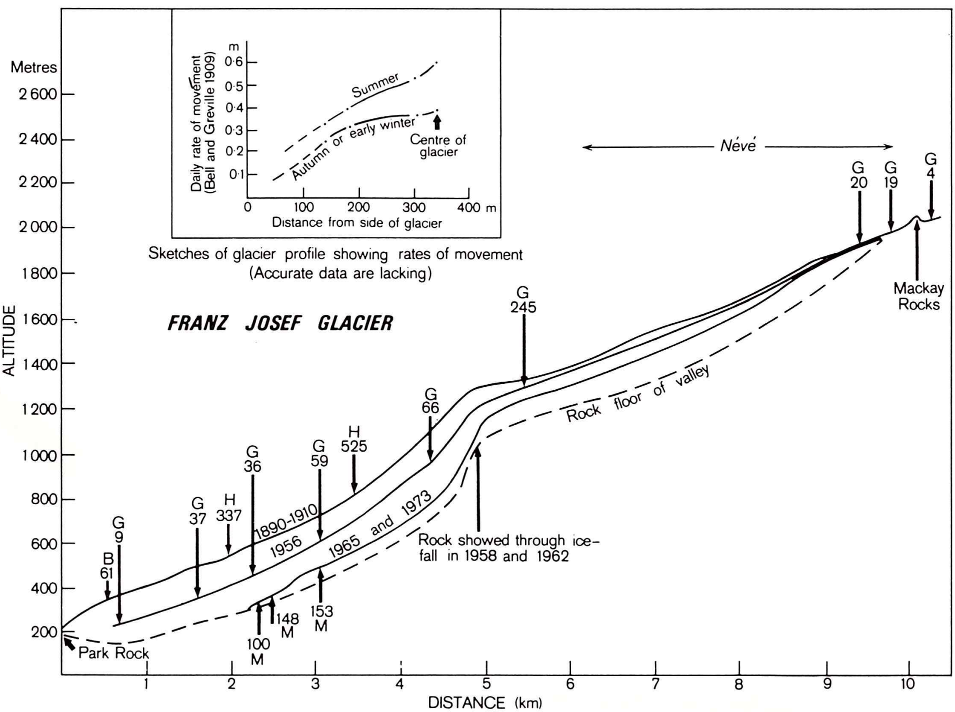
Also shown in fig. 31 are observations made by Bell and Greville from 19 January to 5 March 1909 and from 5 March to 17 July 1909. These observations were made along a line across the glacier about 0.5 km from the terminal face. They show that the glacier moves faster in summer, so that direct comparison of rates shown on the glacier profiles in fig. 31 is not easy. Gunn's rates were obtained by measurements taken during March 1956. Harper's measurements were obtained by compass bearing over periods varying from 3 to 20 days in February 1895.

A good indication of the rate at which the Franz Josef Glacier travelled was obtained by following the progress of an aeroplane which crashed on to the glacier in November 1943 about 3.6 km up from the

terminal face. The wreckage was broken up by glacier movement, and different parts took different courses as they travelled towards the terminal face. Parts of the aeroplane were seen at the terminal face in February 1950, 6 years and 4 months after crashing. From the distance travelled and the time taken, it was estimated that the movement was 1.5 m per day. Some parts of the wreckage moved across the glacier on the downward journey, and their maximum rate of movement would be greater than 1.5 m per day because the glacier moves faster in the middle. This average rate of movement seems much greater than that measured by Gunn in 1956, probably because the 1943–50 period was that in which the glacier was building up and subsequently advanced (in 1946 to 1950).

Fewer measurements have been taken at the Fox Glacier, and no rate as fast as the fastest at the Franz Josef has been recorded. But in the icefall, where no observations have been made, the rate may well be as high as in the icefall at the Franz Josef Glacier.

Figure 31 Profiles of Franz Josef Glacier and rates of movement. Observations on rates of movement: H — Harper 1894; B — Bell and Greville 1909 (*in* Bell 1910); G — Gunn 1956 (*in* Gunn 1964); M — McSaveney and Gage 1966. Rates are maxima, at the centre of the glacier, in cm/day.



Acknowledgments

Thanks are due to Mr Gar Graham, who in 1950 began the weekly photography of the Franz Josef Glacier on behalf of the New Zealand Geological Survey; to the late Mr Peter King, first ranger of the Westland National Park, who took over the photography from Mr Graham; and to Mr Alf Ure, ranger at the park, who now carries out this work.

I am also indebted to Mr Gordon Nicholls, chief ranger, Westland National Park, and Mr Peter McCormack, chief guide, Tourist Hotel Corporation, Franz Josef, for information from time to time, and to Mr Ralph Warburton, photographer, Franz Josef, and Mr Jim Taylor, National Park ranger at Fox Glacier for information and the use of photographs. I also thank the N.Z. Post Office for permission to reproduce the 9d. Peace Issue stamp on the back cover.

Thanks are also due to members of the New Zealand Geological Survey for help in the field, and particularly to Dr R. P. Suggate for his helpful criticism and guidance during the writing of this handbook.

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Glossary

Ablation	The wasting away of glacier ice, mainly by melting.
Cirque	A semi-amphitheatre or deep hollow near the crest of a mountain range caused by glacial erosion, commonly at the head of a glacial valley.
Dead ice	Ice masses detached from the main body of a glacier, usually buried in glacial moraine and no longer moving.
Downwasting	The reduction of a glacier's thickness by ablation.
Glacier tongue	The part of a glacier that is confined by valley walls after leaving the snow fields.
Greywacke	A hard, greyish, marine, sedimentary rock composed of a compacted mixture of sand and silt.
Ice Age	The period during which glaciers advanced from the mountains into the lowlands several times, retreating during intervening times of warmth.
Moraine	An accumulation of sand, silt, and boulders formed by a glacier.
Névé	A mass of snow and ice forming the upper part of a glacier.
Roche moutonnée	A mound of rock, usually smoothed on the upstream side and roughened by plucking on the downstream side, as a result of being over-ridden by moving ice.
Rock flour	Finely ground rock particles, chiefly silt or clay size, resulting from glacial abrasion.
Schist	A common metamorphic rock with layers of different minerals, commonly splitting into thin irregular fragments showing glistening mica.
Snow field	Wide expanse of permanent snow in high mountains.
Trim line	A line marking the former extent of the sides of a glacier along a valley wall. It is formed by advance of the ice into a vegetated area.

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This view of the Southern Alps and Franz Josef Glacier could be seen from the altar window of the Waiho Gorge Chapel in the early 1940s. However, since the retreat of the glacier in the 1950s, the glacier has not been visible from this viewpoint.

The stamp was designed by Mr James Berry, Wellington.

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